



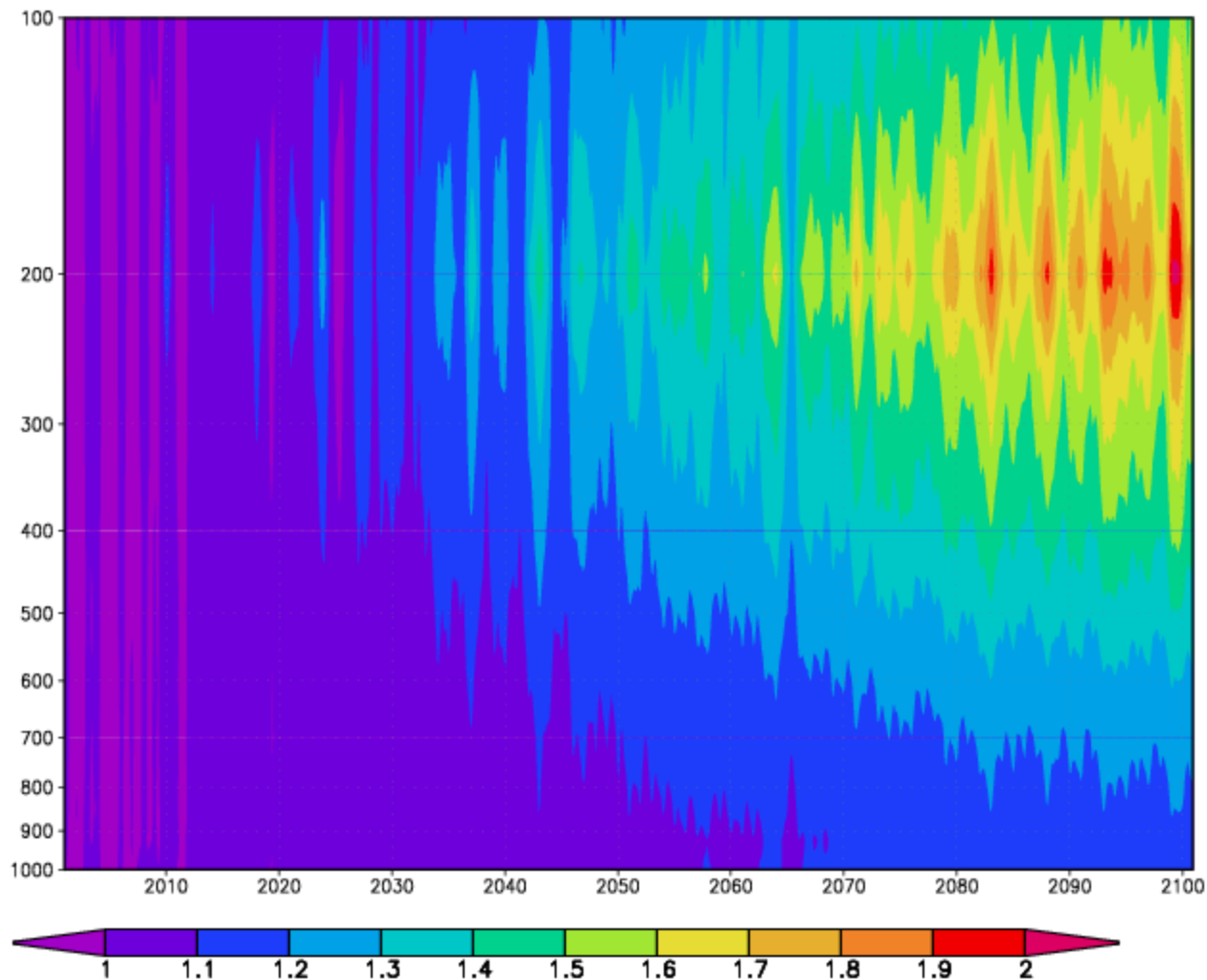
# Detecting Anthropogenic Moistening of the Upper Troposphere

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# Vertical Structure of Water Vapor Change



Upper Troposphere  
Amplification

$$\delta e_s / e_s \sim \delta T / T^2$$

~6%/K @ T=300 K

~14%/K @ T=200 K

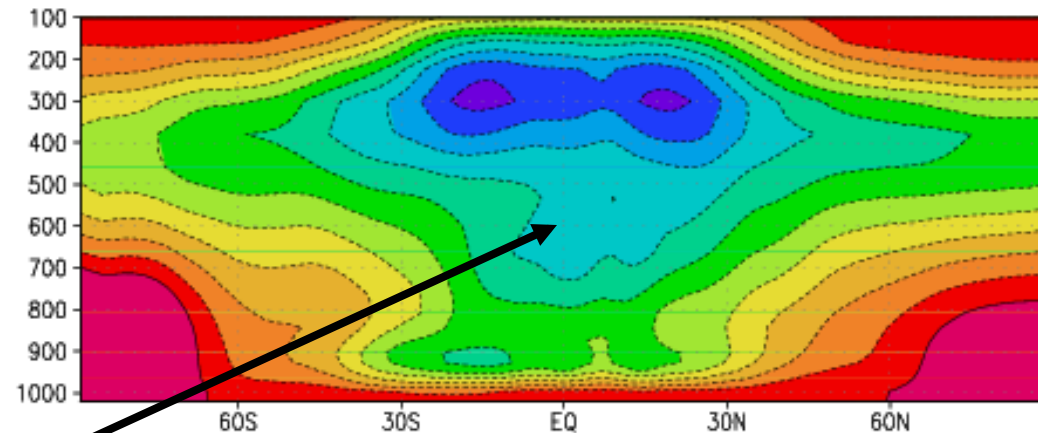
Fractional Change in Water Vapor

# Vertical Distribution of Water Vapor Feedback

Uniform Warming and Constant RH

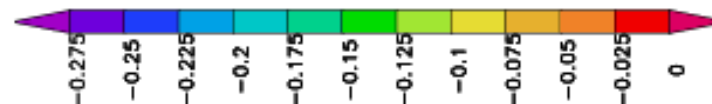
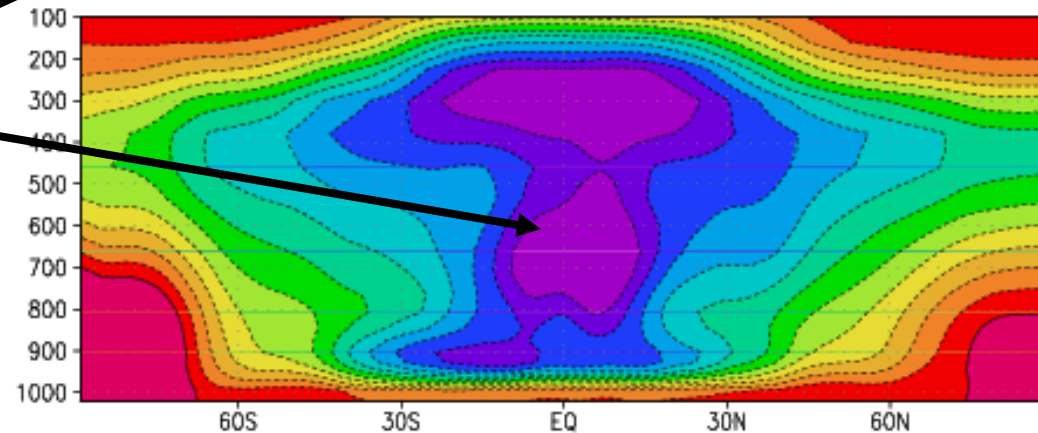
Most feedback from  
tropical upper trop

Total Sky

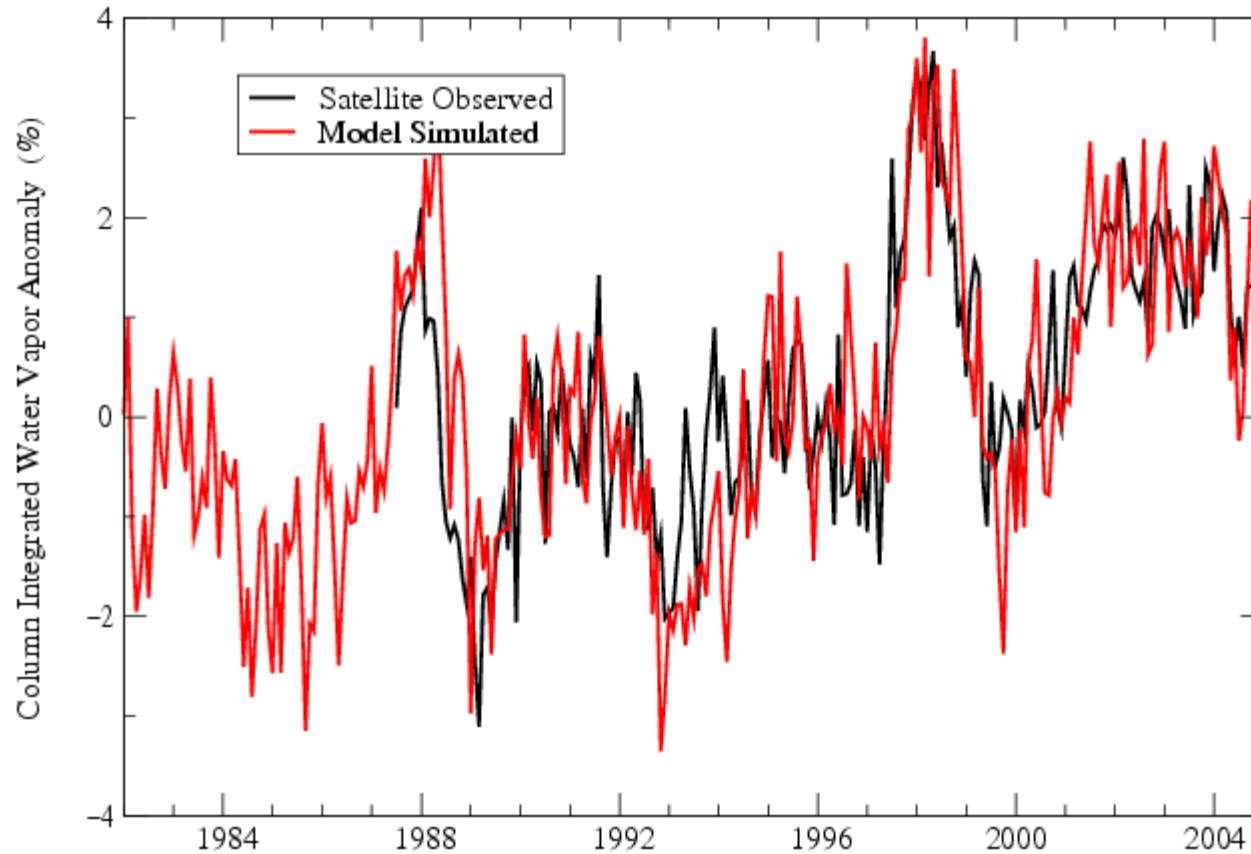


Clouds mask lower  
trop contribution

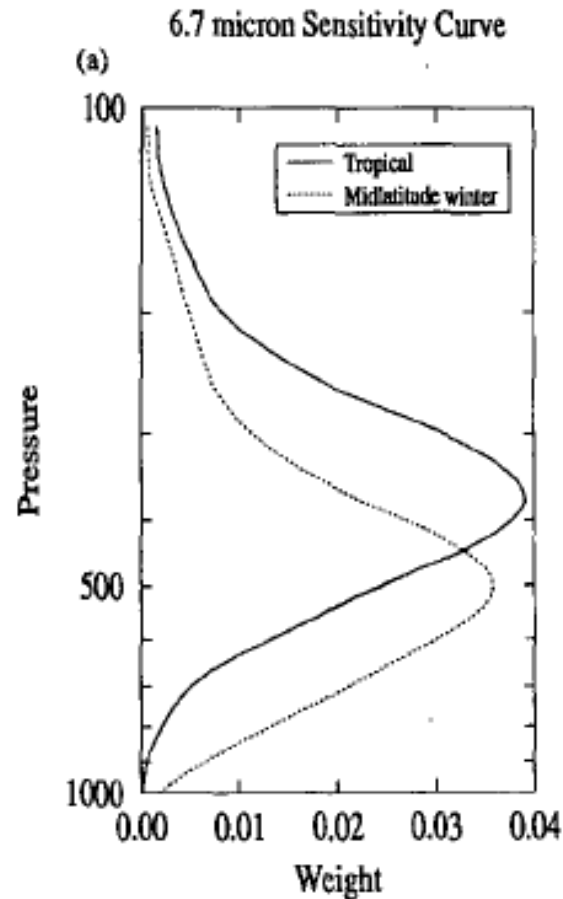
Clear Sky



# Total Column Water Vapor Anomalies (1987-2004)

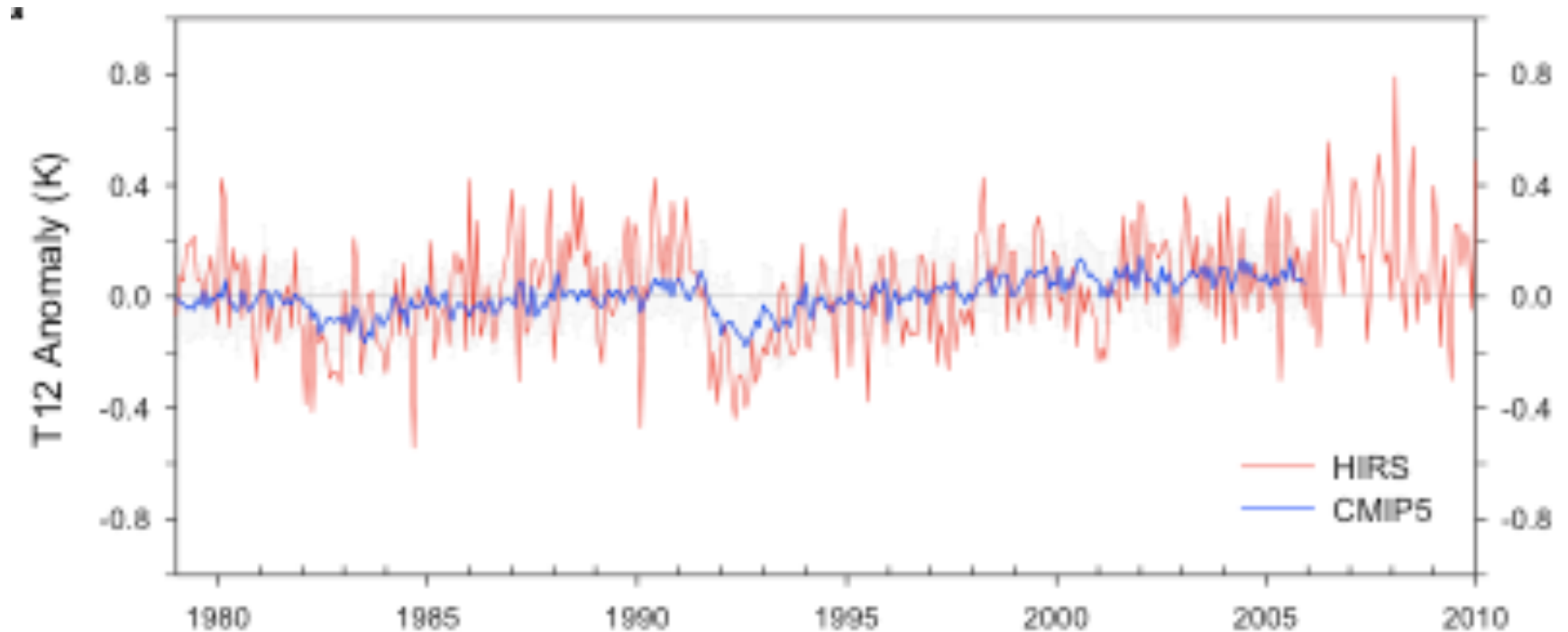


# HIRS 6.7 micron radiances



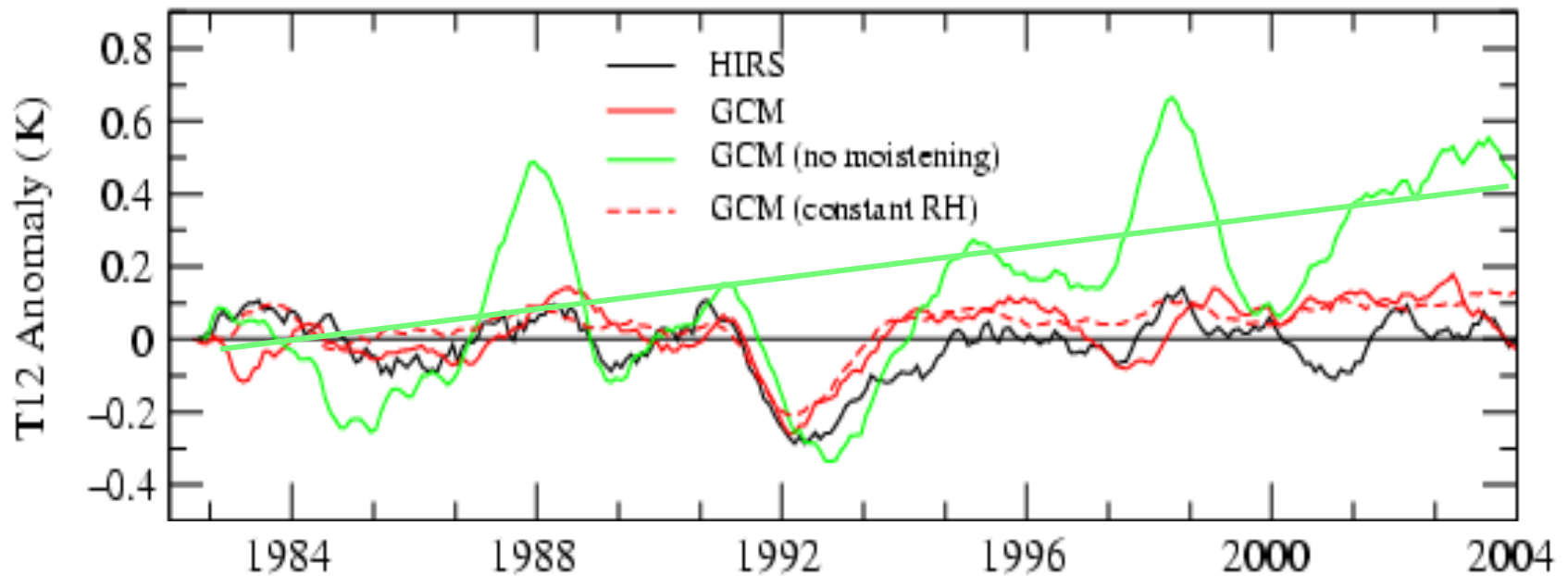
- Sensitive to RH over deep layer of upper trop
- Clear-sky only
- Long record: 1979-2005 (NOAA 6,7,9,10,11,12,14)
- Orbital drift corrected, intercalibrated (Li and Bates, 2010)
- Compare to simulated 6.7  $\mu\text{m}$  radiances from 20 coupled ocean-atmosphere models from CMIP5.

# HIRS T12 Anomalies



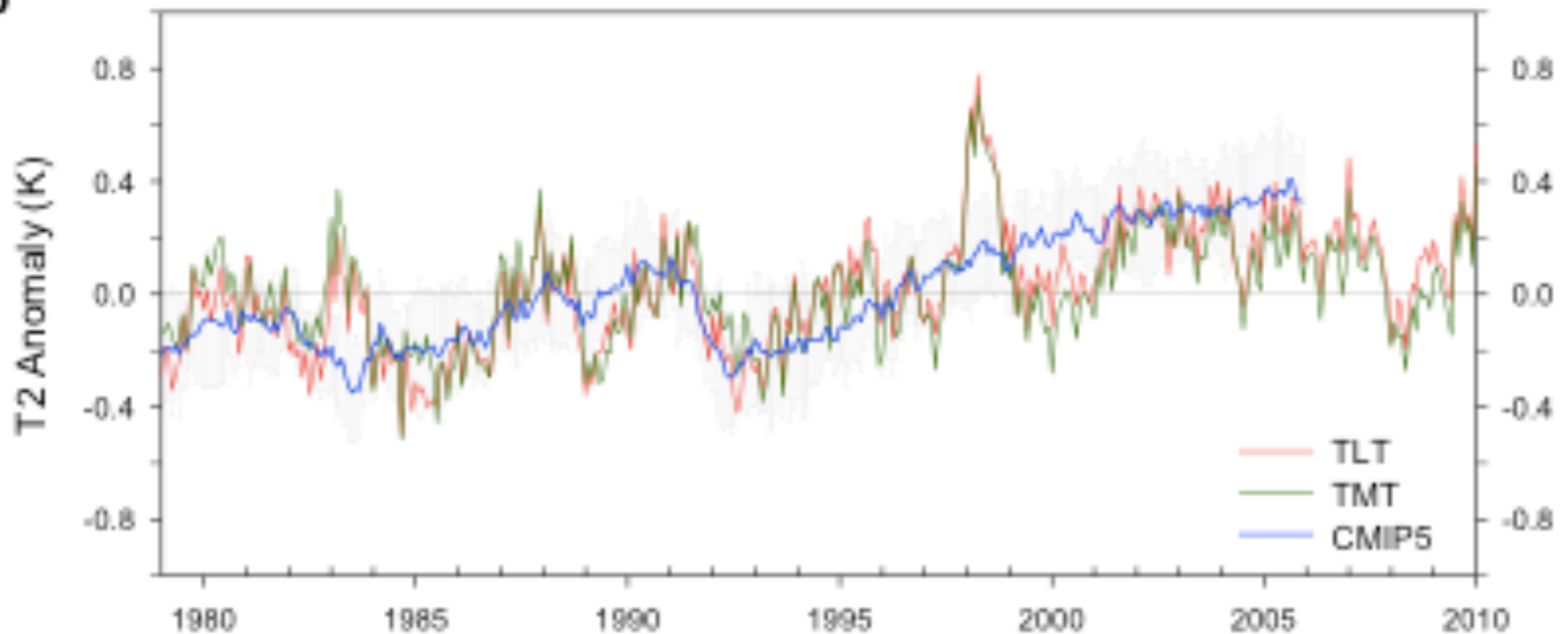
- Observed and CMIP5 GCM simulated T12 show little trend
- HIRS/2 → HIRS/3-4 discontinuity at 2006 due to channel shift

# GCM Sensitivity Studies of HIRS T12



- GCM T12 with constant RH shows no trend
- GCM T12 with fixed mixing ratio increases by ~0.4 K

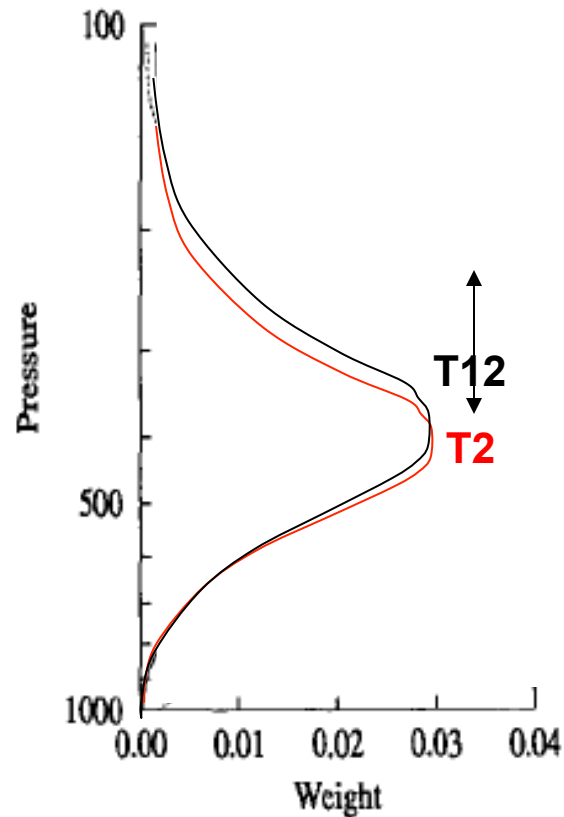
# MSU T2 Anomalies



- Tropospheric temperature increases in both GCM and MSU

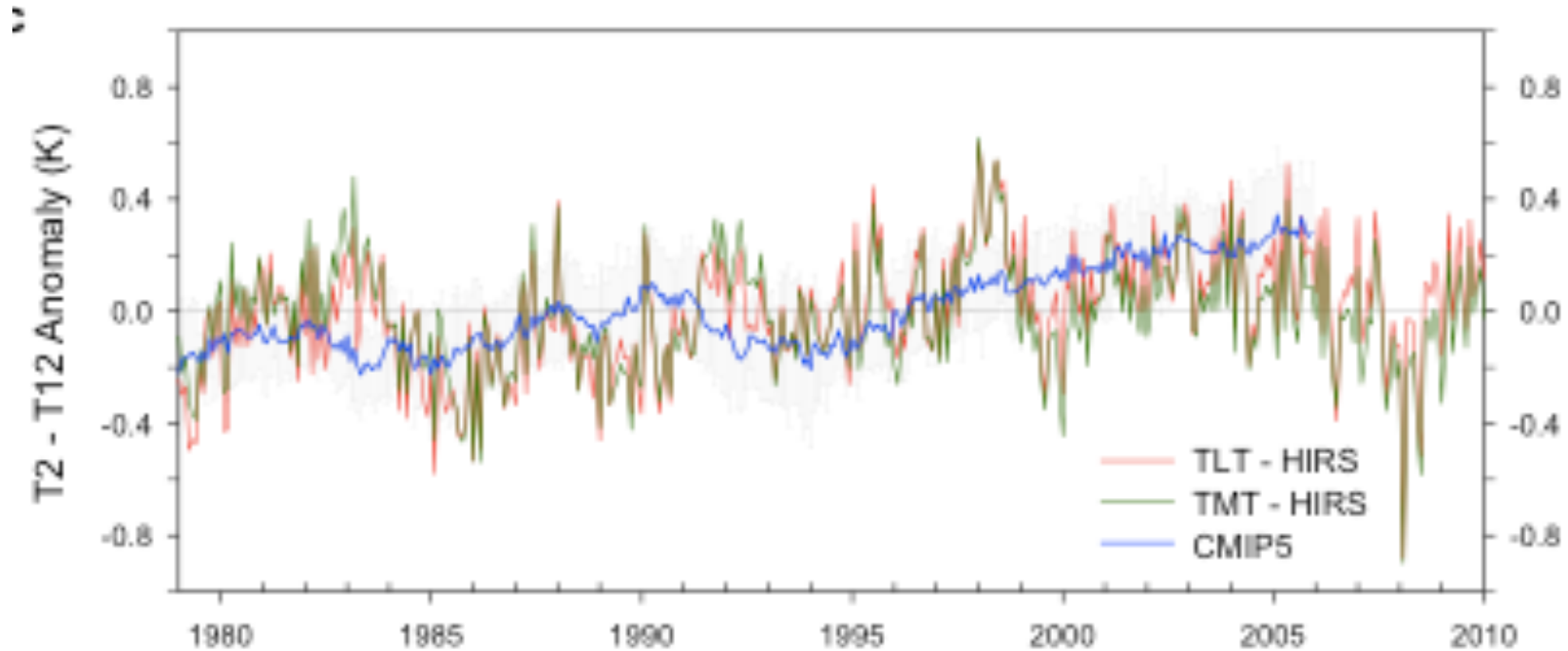


# Emission Levels of T2 and T12



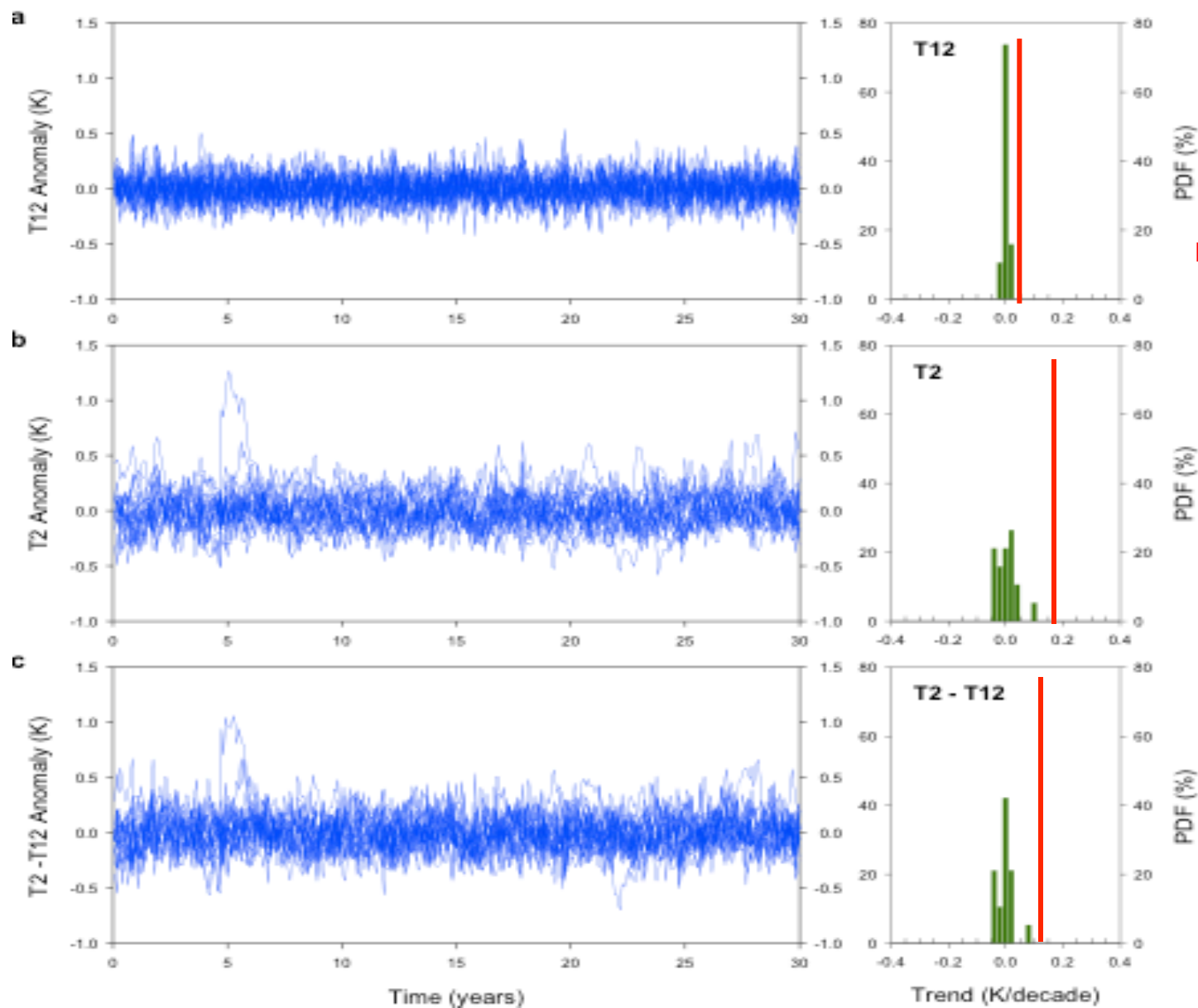
- As UT mixing ratio increases, T12 emission level must increase
- T2 emission level remains fixed (O<sub>2</sub> is not changing)
- So T2-T12 must diverge

# MSU T2 - HIRS T12 Anomalies



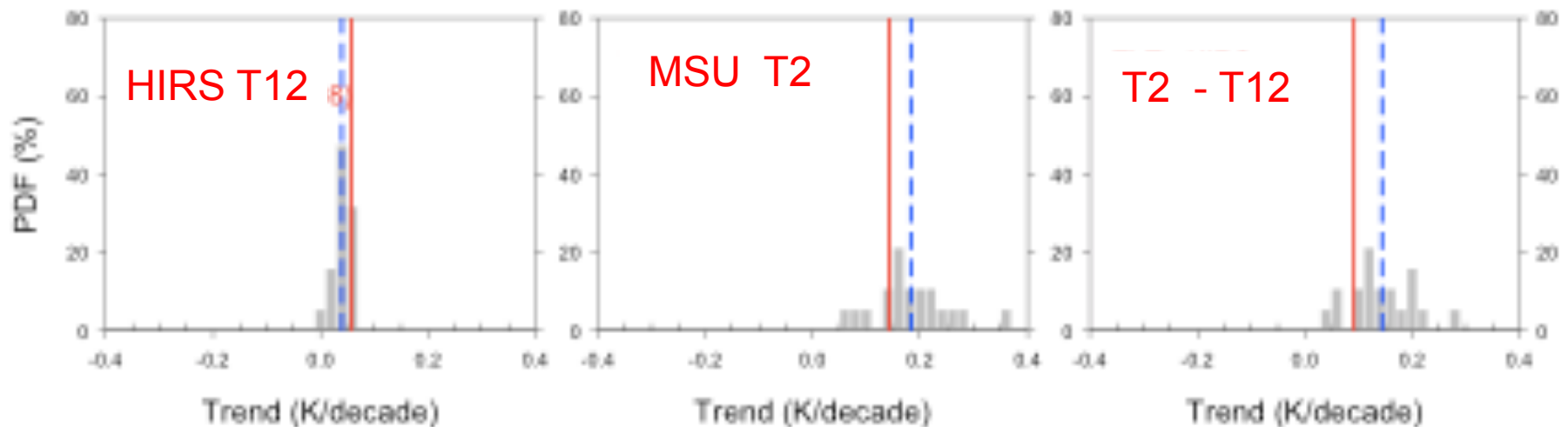
- Emission levels of T2-T12 diverge over past decade by ~0.4 K

# CMIP5 GCM Simulations: Control (Pre-Industrial) Scenario



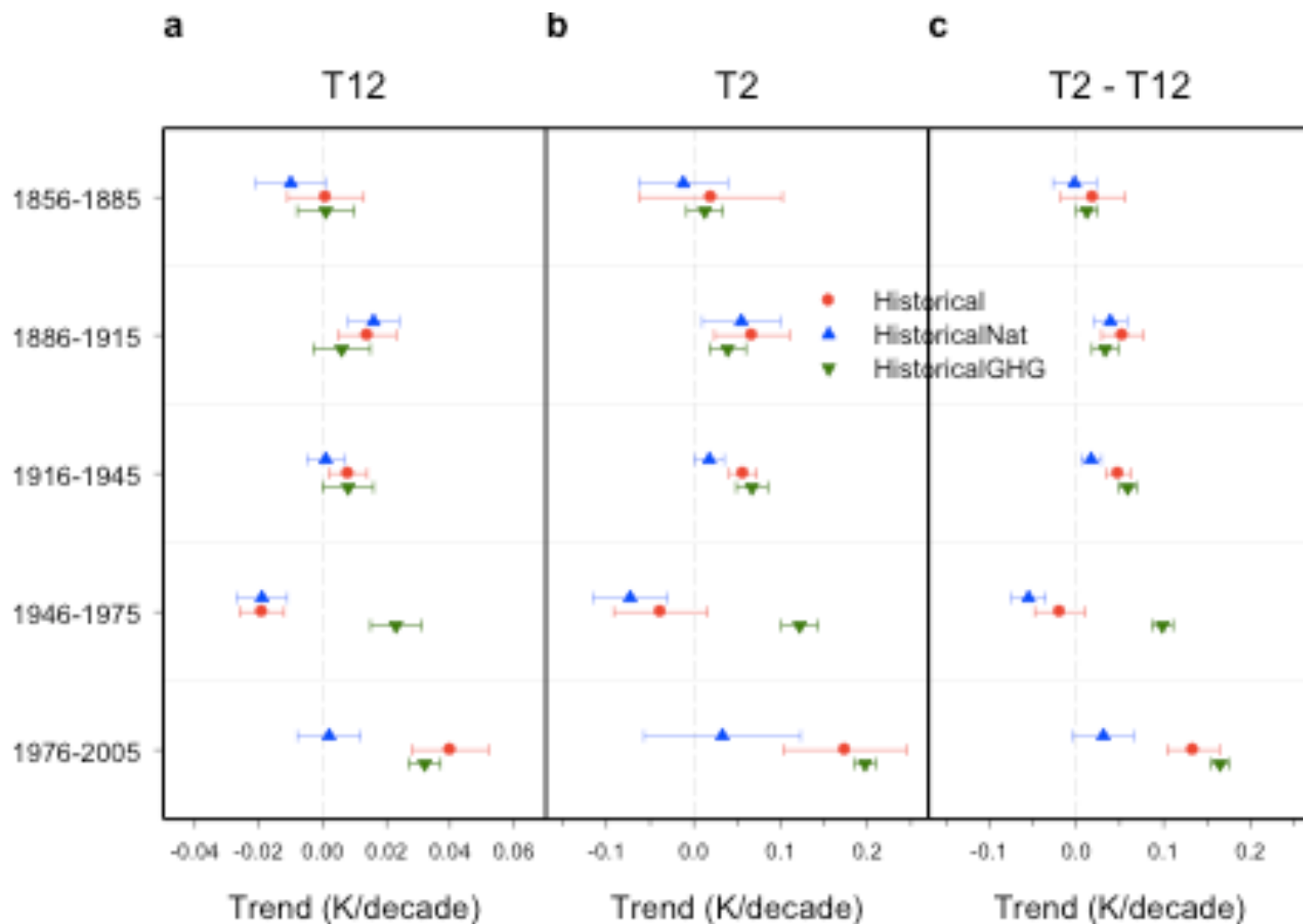
# CMIP5 GCM Simulations: Historical Scenario

PDFs of trend from 20 GCM simulations for 1979-2005  
(Ensemble mean trend ----)



- Observed trends lie within spread of GCM simulations with historical forcing
- Observed moistening trend (T2-T12) is about 30% smaller than ensemble mean due to smaller tropospheric warming trend (T2)

# CMIP5 GCM Simulations: Historical Scenario



# Conclusions

- Models predict the moisture of the upper troposphere should double over the next century due to anthropogenic forcing.
- HIRS provides a method for looking at changes in upper level moisture over the 1979-2005. Continuity of observations after 2005 remains problematic.
- HIRS/MSU show a distinct increase in global UT water vapor over this period.
- The observed trend is consistent with constant RH hypothesis and NOT consistent with a fixed mixing ratio hypothesis.
- The observed moistening is consistent with model simulations under historical forcing scenarios.
- This moistening is primarily due to anthropogenic forcing and can not be explained from natural causes alone.



# Extra Slides